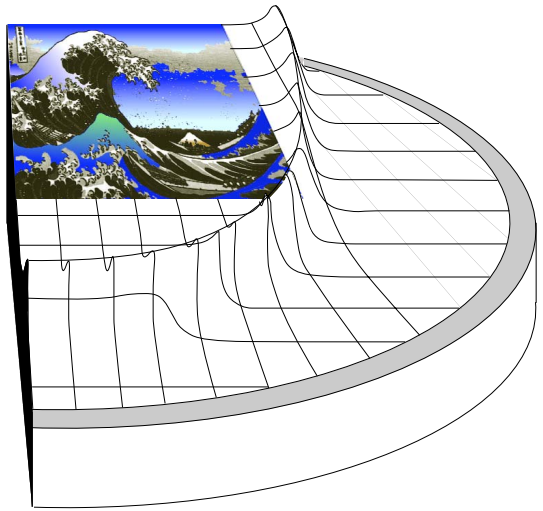
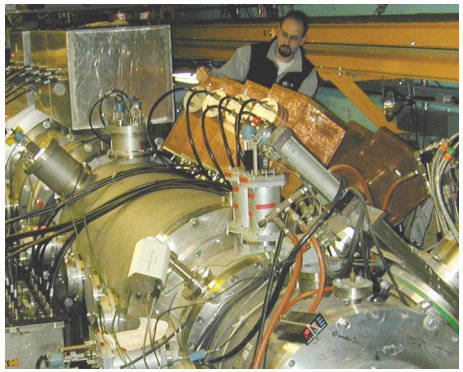
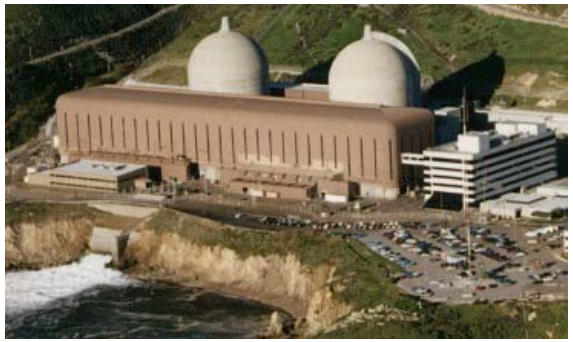
The Future of Nuclear Energy: A California Perspective



Per F. Peterson
Professor
Department of Nuclear Engineering
University of California, Berkeley

California Energy Commission
2005 Integrated Energy Policy Workshop
August 15-16, 2005





CEC Questions

1. **What are the likely costs and benefits of the U.S. Department of Energy's *Nuclear Power 2010* program? To what extent does this program address the four substantial challenges identified by the National Commission on Energy Policy?**
    1. **Cost**
    2. **Accidents and Terrorist Attacks**
    3. **Radioactive Wastes**
    4. **Proliferation Risks**
2. **What is the current status of new nuclear energy technologies? What are the potential safety and cost trade-offs of emerging nuclear reactor technologies and alternative fuel cycles?**
3. **What do you consider to be the major challenges to the continued operation of aging nuclear power plants?**
4. **What are the major challenges for educating and training potential workers to replace the aging/retiring workers at nuclear power plants?**
5. **What are the major challenges and trends in higher education in the field of nuclear energy, including the challenges and trends in student enrollment, fields of study, career opportunities, and the status of educational facilities?**

New nuclear construction: The views in 1995, 2005, 2015

- **Contrast the views of 1995 to the actual 2005 situation**
  - **Popular view**
    - » **Continued trend of early decommisioning**
    - » **Motivation for sales is access to decommissioning funds; plant sales will accelerate decommissioning**
  - **Expert view**
    - » **Opportunity to purchase nuclear capacity at $25/kW**
    - » **Improved management has already demonstrated the capability to rapidly increase capacity factors to ~85%**
- **Now consider 2005 views, versus potential 2015 reality**
  - **Popular view**
    - » **Existing plants are economic, most will receive license renewals,**
    - » **But new plant construction is not economic**
  - **Expert view**
    - » **Construction in 52 months demonstrated for ABWR in Japan**
    - » **New reactor designs achieve large reductions in steel, concrete, and equipment inputs vs. 1990's construction**
    - » **Most important issue is effective construction planning/management**

Capital investments and environmental costs are affected by resource inputs

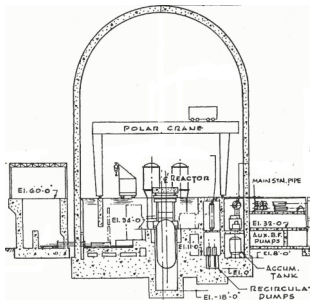
- **Nuclear:** 1970's vintage PWR, 90% capacity factor, 60 year life [1]
  - 40 MT steel / MW(average)
  - 190 m^3 concrete / MW(average)
- **Wind:** 1990's vintage, 6.4 m/s average wind speed, 25% capacity factor, 15 year life [2]
  - 460 MT steel / MW (average)
  - 870 m^3 concrete / MW(average)
- **Coal:** 78% capacity factor, 30 year life [2]
  - 98 MT steel / MW(average)
  - 160 m^3 concrete / MW(average)
- **Natural Gas Combined Cycle:** 75% capacity factor, 30 year life [3]
  - 3.3 MT steel / MW(average)
  - 27 m^3 concrete / MW(average)

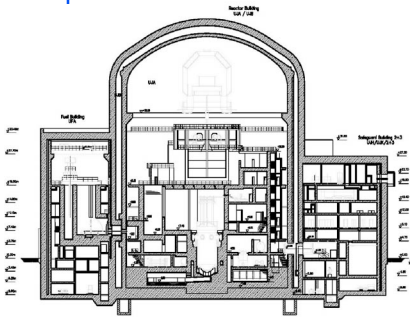
Concrete + steel are >95% of construction inputs, and will become more expensive in a carbon-constrained economy

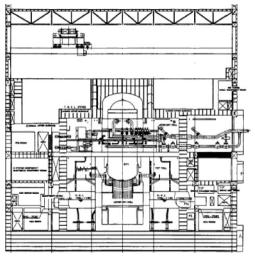
1. R.H. Bryan and I.T. Dudley, "Estimated Quantities of Materials Contained in a 1000-MW(e) PWR Power Plant," Oak Ridge National Laboratory, TM-4515, June (1974)
2. S. Pacca and A. Horvath, *Environ. Sci. Technol.*, **36**, 3194-3200 (2002).
3. P.J. Meier, "Life-Cycle Assessment of Electricity Generation Systems and Applications for Climate Change Policy Analysis," U. WisconsinReport UWFDM-1181, August, 2002.

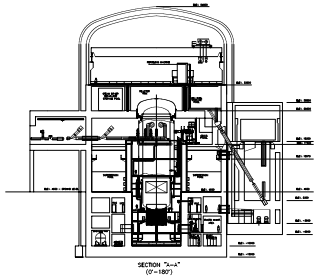
The new passive reactor designs (e.g., ESBWR/AP1000) reverse the trend of increasing steel and concrete inputs

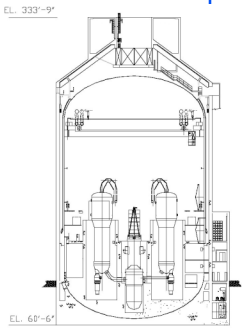
Gen II | **Gen III - Active** | **Gen III+ - Passive**

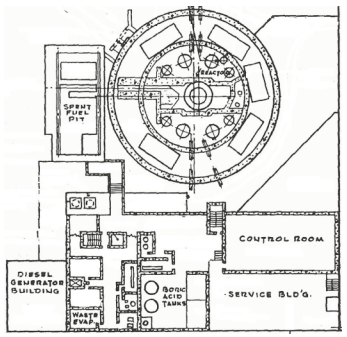


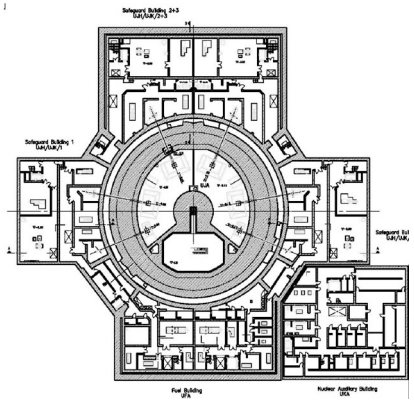


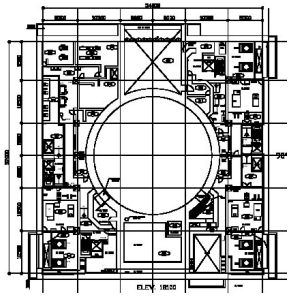


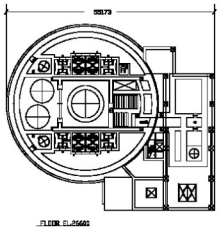


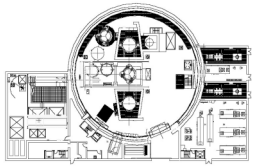












1970's PWR
1000 MWe
40 MT_{steel}/MW

EPR
1600 MWe
49 MT_{steel}/MW

ABWR
1380 MWe
51 MT_{steel}/MW

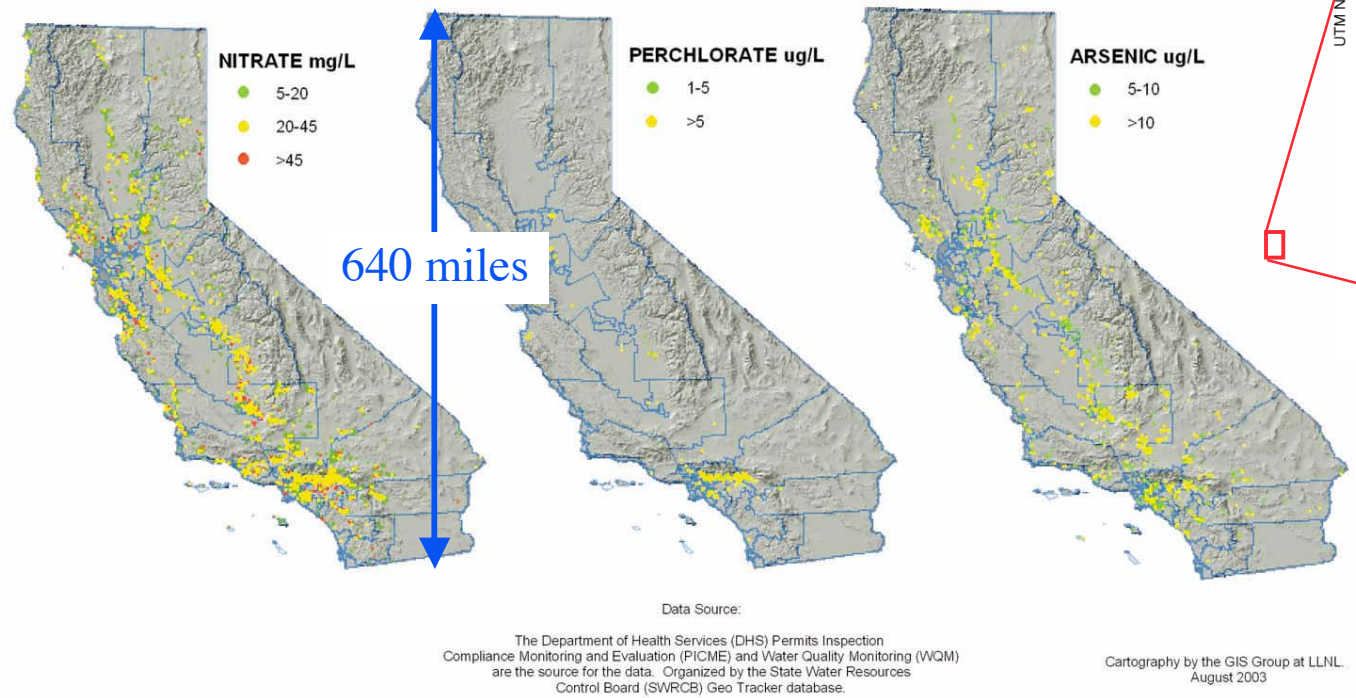
ESBWR
1500 MWe
37 MT_{steel}/MW

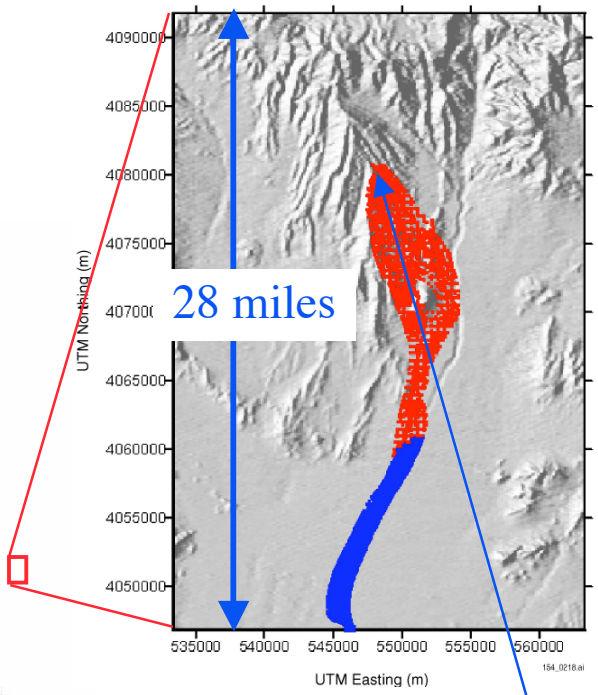
AP-1000
1090 MWe

This has implications for the likely capital costs of the plants selected by Nustart for COL development (ESBWR/AP1000)

Fossil and chemical wastes use create the most important 20th century legacies -- not nuclear waste

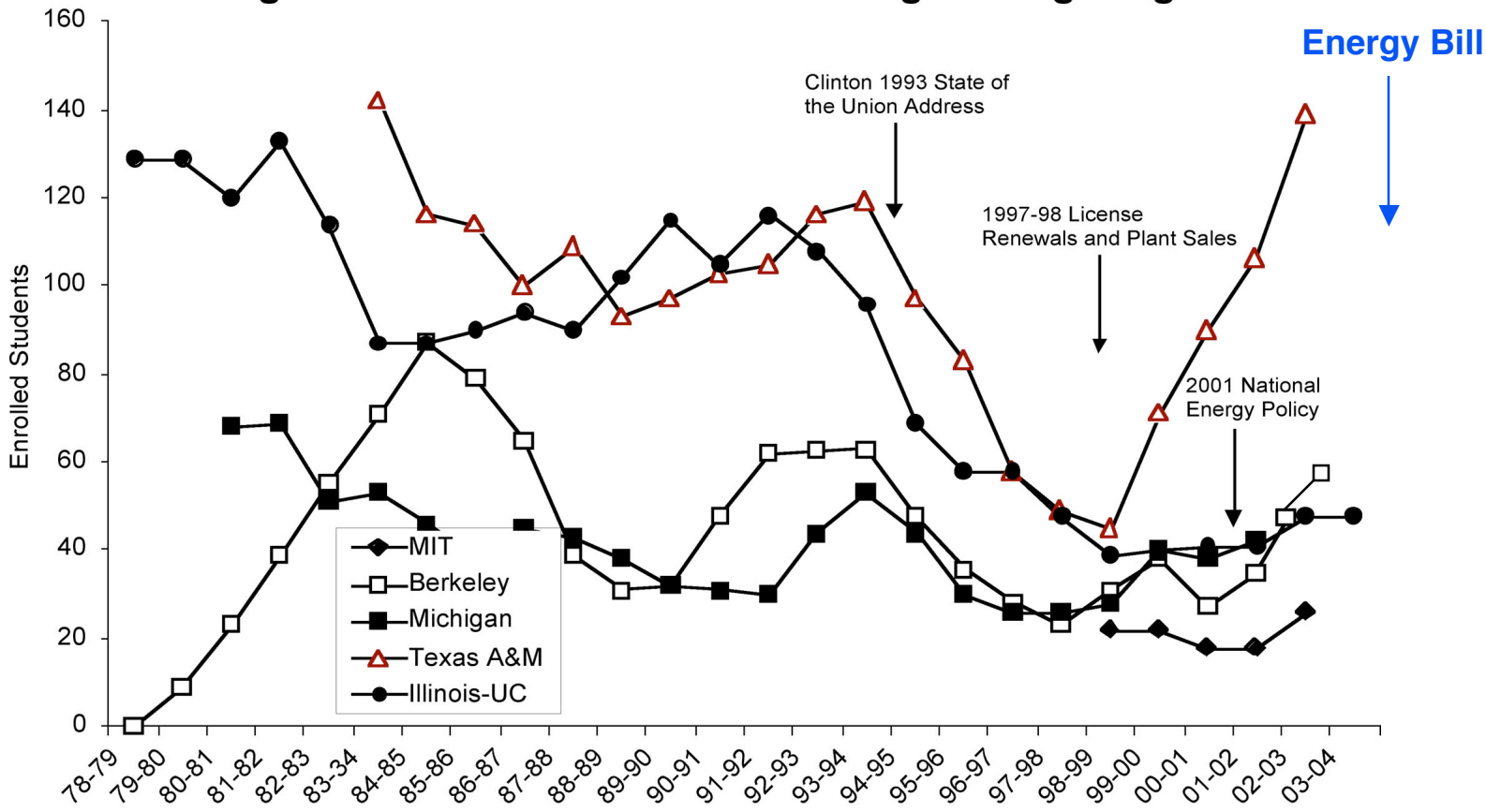
Scaled comparison of California wells with current nitrate, perchlorate, and arsenic groundwater contamination, to the potential groundwater plume that might be generated at Yucca Mountain





Equivalent of 5 to 500 billion tons of coal mining/combustion, depending upon fuel cycle

Undergraduate Enrollment in Nuclear Engineering Programs



Source: University Records

Conclusions

- **France closed its last coal mine in April 2004**
  - **Transition from 15% to 80% nuclear electricity accomplished in 20 years**
  - **France provides empirical proof that nuclear energy can—technically and economically—displace fossil energy at large scale**
- **U.C. Berkeley's Department of Nuclear Engineering looks forward to supporting California in identifying the potential future role for nuclear energy**